A comparison of the performance of learners transitioning from TVET college and their certificated high-school counterparts

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ABSTRACT

Situated in an Engineering Department at a University of Technology, this quantitative research, traversing the fields of Engineering, Mathematics and Education and using the positivism paradigm or 'science research', investigated the efficacy of the National Articulation Policy. According to this policy, learners not gaining direct entry to a University of Technology armed with a Senior Certificate or a National Senior Certificate (SC/NSC) may progress or 'articulate' into a chosen Engineering programme after attending a Technical and Vocational Education and Training (TVET) college. Employing statistical analysis on cohorts of learners from TVET colleges, this study was able to determine that there was no statistically significant difference between the performance of the articulating learners and that of their SC/NSC counterparts straight out of high school.

KEYWORDS

Articulation, TVET, admission requirements, STEM, engineering, throughput

Introduction

The Engineering Department at the Durban University of Technology (DUT) situated in the province of KwaZulu-Natal has, since 1994, accepted for enrolment learners from Technical and Vocational Education and Training (TVET) colleges who were not initially in possession of the entrance requirements for registration for the National Accredited Technical Education Diploma (NATED 191) National Diploma: Electrical Engineering. This decision was based on the positive perceptions of the academic staff that the learners' updated knowledge and abilities enabled them to cope with the complexity and quality of Engineering programmes, because those learners were entering the institution directly after completing their school-leaving Senior Certificate or National Senior Certificate (SC/NSC). The SC/NSC is the exit-level certificate from traditional high schools in South Africa. This belief is not consistent among all the stakeholders, as many have negative perceptions of the TVET education system (Malale & Gomba, 2016). No formal tracking, analysis or research had been conducted to determine the success or failure of these learners at a University of Technology (UoT). These learners are defined according to the Articulation Policy for the Post-School Education and Training System of South Africa (PSET) (DHET, 2017) in terms of section 8(2)(*b*) of the National Qualifications Framework Act 67 of 2008 (NQF) (DHET, 2009). The present investigation, based on an Engineering learner dataset, therefore set out to determine statistically whether the learners defined in this way are as successful as their first-time SC/NSC counterparts. This research is of importance not only to UoTs and TVET colleges, but also to learners, policy-makers and the general public.

Background

The education systems in South Africa prior to 1994 were restrictive (Case, 2006) and limited the prospects of learners of colour from entering an institution of higher learning and gain a higher education (HE) (DOL, 2010). In contrast, and to remedy that situation, section 29 of the South African Constitution (RSA, 1996) states:

> 29. (1) Everyone has the right—
> (*a*) to a basic education, including adult basic education; and
> (*b*) to further education, which the state, through reasonable measures, must make progressively available and accessible.

In accordance with this constitutional provision, the Government of National Unity post-1994 initiated the process of restructuring the education system, which is now governed by the NQF (DHET, 2009). The relevant Act of Parliament applies to all educational programmes that lead to qualifications or part-qualifications offered in the Republic of South Africa.

In line with the legislation and the myriad changes that occurred in the education, economic and social spheres post-1994 in South Africa, HE underwent changes in the number and demographics of the former white higher educational institutions (HEIs) and in industry. Despite the massification of learners in HEIs, and changes in the demographics of the membership of the professional bodies for Engineering (Case, 2006), a reduction in throughput rates in HE resulted in what is referred to as the 'skewed revolution' (Cooper & Subotzky, 2001, as cited in Bundy, 2006). The term refers to the enrolment of previously disadvantaged learners in the Humanities rather than for studies towards Business, Technology and Science degrees.

In alignment with the National Plan for Higher Education (DOE, 2001) and in response to the demand from industry (Cosser, 2010), the Engineering Department currently has the human resources, facilities and equipment to enrol 120 learners in the programme annually. The aim of attaining these enrolment figures is to increase the rate of participation of learners in Science, Technology, Engineering and Mathematics (STEM) and to sustain the pipeline supplying industry with sufficient graduates. Despite the more than 2 500 applications for enrolment for degree courses in the Engineering Department annually, the majority of learners (94%) do not meet the minimum universitya and departmental entrance requirements of an SC/NSC (DBE, 2012) or a pass mark (level 4) in Mathematics, Physical Science and English. This is largely because they are underprepared academically (Oosthuizen, Garrod & Macfarlane, 2009). As a result, the planned enrolment numbers are not always achieved (see Table 1). This situation has been exacerbated by the department's introduction of a degree programme in 2018 that requires learners to have combined percentage points of a minimum of 120 for Mathematics and Physical Science at SC/NSC level. The change from the diploma to the degree programme, which is supported and promoted by industry and aligned to the Higher Education Qualifications Sub-Framework (HEQSF), necessitated this adjustment to reflect the level and status of a degree qualification. This trend is being experienced in the STEM sector generally (Case, 2006; DHET, 2013; IEEE, 2013; Graham, Lortan, Maistry & Walker, 2017; SAQA, 2019).

TABLE 1: Learners entering first year of Engineering

BEng Tech: Power Engineering	
Year	**No. of first-year learners**
2018	97
2019	116
2020	112
2021	70

Context

Challenges in the education system in South African high schools are negatively affecting the success of learners in HEIs; this is now labelled the 'articulation gap' (Mawoyo, 2014; Scott, 2014). This articulation gap creates difficulties for many learners entering HE at the first attempt. As reported by McGhie (2014), one of the factors negatively affecting learners' transition from high school to university is that the challenge of transition is often too great. This results in students failing or dropping out of their studies. Secondly, the importance of new learners successfully transitioning has both immediate and long-term implications for student retention at each HEI: a high dropout rate affects graduation rates and the concomitant funding that accompanies them (CHE, 2015). Against this background, it is understandable that HEIs should be interested in admitting learners who are most likely to complete their qualifications in the usual minimum time (3–4 years). Second-chance learners – applicants who do not access HE at the first attempt – are more likely to be marginalised by this approach. However, second-chance learners also need to have opportunities created for them that will enable them to enter HEIs for what is termed a 'second-chance education'. Ross and Gray (2005) explain that second-chance education is based on the idea that by being progressed through an organised structure, an individual can take up an educational opportunity missed or failed the first time round.

One mechanism that enables second-chance education is articulation. Articulation refers to the mechanisms that enable learner mobility within and among the institutions that comprise the tertiary system. For example, by accumulating and transferring academic credits, recognising degrees between institutions and their equivalence, the recognition of prior learning, and so on (Ng'ethe, Subotzky & Afeti, 2008), it is possible for students to move between HEIs.

Notwithstanding the promulgation of the Articulation Policy in 2017, challenges of varying complexity arise when an individual transfers from a TVET college to a UoT or a traditional or comprehensive university. The South African Qualifications Authority's (SAQA, 2017) *Baseline Study Report* established that most HEIs have a variety of approaches to articulation, with no clear or standard process that is followed; this is a common challenge for individuals intending to articulate within or across the PSET sector. The Articulation Policy has been developed to overcome the barriers that exist in HE. It has also highlighted a number of barriers to articulation (DHET, 2017), four of them being the most relevant to this investigation:

- Academic qualifications are considered more valuable and credible than comparable vocational or occupational qualifications.
- Some qualifications in the NQF are seen to be 'dead end' in nature and do not lead to further learning.
- There are general perceptions that the purpose and nature of TVET is to offer learning programmes which focus on a relatively narrow band of employment-related or job-specific skills and competencies, when in fact the qualifications and/or part-qualifications could have wider relevance.
- There is a general lack of institutional flexibility to support learners as they 'step in and step out' of their studies, where research has shown that this kind of 'staggered pathway' is the norm at all NQF levels.

In summary, these barriers point to a lack of parity of esteem between academic qualifications, on the one hand, and technical and vocational qualifications, on the other, and this has led to the misperception that the quality of these TVET college qualifications and of the learners they produce is inferior.

Literature review

Having sufficiently skilled and qualified professional engineers is recognised by the Ministries of Labour and of Trade and Industry as being vital to the development of South Africa's infrastructure and economic growth (IEEE, 2013). In a comparative study by Lawless (2005, as cited by Case, 2006), of the number of engineering professionals, South Africa had 315 registered engineers per million of the population. Japan had 3 300, whereas the United Kingdom and Norway had 3 220 and 8 190 engineers per million of their respective populations (Case, 2006:7). Little change has been seen in these figures since 2005, as reflected in the Engineering Council of South Africa's Annual Report for 2018. The report reveals that there are 17 226 registered engineers in a population of 56 million, of which 80.7% or 13 903 are white, 11.5% or 1 985 are black, 6.7% or 1 144 are Asian, and 1.1% or 194 are Coloured. Approximately 1 500 engineers graduate every year, with only 50% going on to practise (ECSA, 2017:84). This statistic is an indictment on South Africa's economic health. As described previously, many learners exit the South African basic education system in possession of an SC/NSC but without the necessary entrance requirements for admission to the HEI programme of their choice.

Many reasons have been proffered for the poor performance of learners in the SC/NSC subjects. Reddy has indicated that South African Mathematics and Science educators' standards have been benchmarked internationally as being among the lowest in the world (Reddy, 2006). Furthermore, the *Trends in International Maths and Science Study's* (Boston College, 2019)[1] assessment of Grade 8 learners indicated that South Africa was placed last for Science and second last for Mathematics in 2019 (Boston College, 2019). This strongly suggests that SC/NSC learners leave the school system with very weak Mathematics and Physical Science marks. As these subjects constitute part of the entrance criteria for all Engineering programmes at South African HEIs, many aspirant engineers are denied admission to HE Engineering qualifications. The same learners, however, if able to articulate into HE through an alternative route such as an Engineering N4 Certificate, having obtained relevant knowledge and necessary competency, would be provided with another opportunity to be admitted in a shorter time via an appropriate avenue. Articulation has provided learners with a streamlined means of obtaining a second chance to be admitted to an HEI without having to spend another year repeating the entire set of Grade 12 subjects or even attempting a supplementary examination, which leads to a lost year. A well-articulated system, as

1 TIMSS data have been collected from learners at Grades 4 and 8 every four years since 1995, with the United States participating in every administration of TIMSS. TIMSS Advanced studies the achievement in advanced Mathematics and Physics of learners in their final year of secondary school. It was conducted in 1995, 2008, 2015 and 2019, with the United States participating in 1995, 2015 and 2019.

summarised in the Articulation Policy (DHET, 2017), is one that would provide such a route as it

> is one in which there are linkages between its different parts: … no silos, no dead ends. If a learner completes a course at one institution and having gained the relevant knowledge and skills at the necessary levels, their achievements must be recognized by other institutions if the knowledge gained is sufficient to allow epistemological access to programme(s) that the learner wants to enter. Learners must be supported in their individual learning and work pathways (DHET, 2017).

The Articulation Policy underpins the principles of the constitutional right to education through reference to mobility, progression and establishing career paths for learners. In terms of the policy, articulation routes should be developed to ensure that learning pathways are practically and logically linked to facilitate smooth learning pathways for learners wanting to raise the level of their education. In support of this, the DUT/SAQA National Articulation Baseline Study of 2017 (NABS) (SAQA, 2017), conducted across 50 public TVET colleges and 26 public HEIs, determined an understanding of articulation in the form of descriptions of existing articulation arrangements and the challenges arising from articulation. It also included an investigation into existing successes and enablers and probed the extent to which the accurate tracking of learners' movements into, through and out of the institutions was taking place. Moreover, several suggestions were summarised in support of the implementation of the Department of Higher Education and Training's (DHET) Articulation Policy and the NQF policy suite. One of these recommendations – that 'systematic reporting requirements and guidelines for institutions to track and report on articulation practices should be developed' – provided the impetus for this study.

Theoretical and methodological framework

This quantitative study was conducted using a framework of positivism and inferential statistical analysis and techniques. As previously mentioned, the theoretical framework – separate from the theory – refers to the paradigm (Bogdan & Biklin, 1998; Mertens, 2005) in which the study is positioned; it provides direction for the intention, motivation and expectations of the researcher (Mackenzie & Knipe, 2006). Positivism, one such paradigm referred to as the 'scientific method' or 'science research', is 'based on a rationalistic, empiricist philosophy in which cause affects outcome' (Creswell, 2003:7). The positivists test a theory 'through observation or measurement, in order to control forces that surround us' (O'Leary, 2004:5). Positivism was replaced by post-positivism after World War II, and as Cook and Campbell (1979) remind us:

> Post-positivists work from the assumption that any piece of research is influenced by a number of well-developed theories apart from, and as well as, the one which is being tested (Cook & Campbell, 1979:24).

Post-positivist and positivist research is most commonly aligned with quantitative methods of data collection and analysis.

Accordingly, the present study sets out to determine the accuracy of long-held perceptions among academic staff: first, that learners articulating into HEI from TVET colleges can complete the National Diploma and, second, if they can, they do so within the same time frame as their SC/NSC cohort. The data analysed in this research are obtainable from the UoT's Management Information System (MIS). The research proposal for this study was reviewed by the UoT's Faculty Research Committee for Engineering and the Built Environment. Approval was granted on 12 June 2020, with ethical clearance category 1. It is noteworthy that the MIS is not able to differentiate between the TVET and the SC/NSC learners, and therefore all the data had to be sorted manually to extract the two sets of learners. After extraction and sorting, the data were analysed to determine the success and/or failure of the cohort of learners articulating from TVET colleges into the National Diploma: Electrical Engineering at the UoT from January 2013 to July 2017. These learners had completed four N4 subjects: N4 Engineering Mathematics, N4 Engineering Science, N4 Electrotechnics and N4 Industrial Electronics, all at the equivalent Level 4. The learner enrolment data and the results for first-level subjects were captured for analysis.

A total of 154 TVET N4 learners were identified. Of these, the information for 87 of them was missing or incomplete. These learners had been captured on the MIS system simply as 'Passed' and no symbol was attached to the subject. This reduced the number of learners in the dataset to 67. A total of 646 SC/NSC learners were captured during the same period (January 2013–July 2017). Only 100 learners' information was excluded due to missing information – reducing the SC/NSC dataset to 546. Even though the group sizes were different, appropriate non-parametric tests were done to factor this in so that the group sizes became comparable. The non-parametric tests included the Mann-Whitney U and the Fisher Freedman tests.

The scope of the Articulation Policy (DHET, 2017) clearly encompasses Basic Education, TVET and HE, therefore encompassing all the spheres of this research. The Articulation Policy defines articulation in three ways as:

- *systemic* articulation – that which is based on government legislation or various other official elements aligned to and supportive of learning and work pathways; or
- *specific* articulation – that which is based on agreements between institutions in the education system, such as Memoranda of Understanding (MoU); or
- pathways followed by individuals as they progress with the support of the institutions (DHET, 2017).

In the absence of any systemic articulation policies other than the National Policy itself, articulation is therefore specific and relies on engaging in 'boundary-crossing practices'

(SAQA, 2017). Learners encounter boundary zones between differing elements of learning pathways and will need to engage in 'boundary-crossing practices' when navigating their learning pathways (Lotz-Sisitka, 2015; SAQA, 2017). These practices or this support reduces the gap between the policy development and implementation related to learning pathways, strengthening specific pathways and enhancing the opportunities to progress along these pathways, the quality of education and training, Flexible Learning and Teaching Provision, appropriate career advice, and various other types of support required (Lotz-Sisitka, 2015).

Blom (2013) describes articulation as being deceptively simple but does admit that deliberate and considered effort has to take place to enable learners to progress along practical and logical learning and career pathways. Blom (2013) proffers a description of 'articulation as a stairwell' as one method of articulation. This method gives second-chance learners who did not meet the requirements for entry into a programme at their first attempt a second opportunity to gain entry. This would present learners from the Basic Education system with another opportunity to meet the entrance requirements of their desired HE programmes by completing relevant and outstanding subjects at a TVET college. The Engineering Department at the UoT developed an 'articulation as a stairwell' initiative which directed learners who did not meet all the admission requirements to TVET colleges to register for those subjects preventing their admission to their qualification of choice. Upon successful completion of these subjects, learners may articulate into the National Diploma: Electrical Engineering at the UoT. This approach was predicated upon the critical shortage of learners in possession of the required Mathematics and Physical Science results and the need to admit them to study in the department. As this shortage is experienced nationally by HE Science and Engineering programmes (DOL, 2010), learners from TVET colleges constitute a potential source of learners for HE programmes in STEM.

Findings

The statistical analysis was undertaken using SPSS version 27.0. The descriptive statistics are presented in the form of graphs, cross-tabulations and other figures for the quantitative data that were collected. Inferential techniques include the use of regression and the chi-square test values, which are interpreted using the *p*-values. The traditional approach to reporting a result requires a statement of statistical significance. A *p*-value is generated from a test statistic. A significant result is indicated by '$p < 0.05$'.

In total, the results of 546 SC/NSC learners and 67 N4 learners were analysed. This section uses descriptive statistics to evaluate the patterns in the data. The Kolmogorov tests indicated that the data were not normally distributed. Central measures are described using means and medians, with the spread estimated by the standard deviation and inter-quartile ranges respectively. (The inter-quartile range is the difference between the 3rd quartile and the 1st quartile values.)

A comparison of the English First (English A) and English Second (English B) language results of the two cohorts was undertaken within each group prior to the commencement of the testing procedures. The null hypothesis claims that there is no difference between English A and English B results. The alternative hypothesis claims that there is a difference between the two (see Table 2). Although English A and English B learners would have different English competency levels, this research study was unable to use these results to draw any conclusions.

TABLE 2: Comparisons between English A and English B results

GROUP	*P*-VALUE
SC/NSC	0.054
TVET N4	0.424

In both instances, there is no significant difference in the scores for English A and B. Hence, the English score was treated as a single entity (referred to here as Combined English).

Comparisons of scores between the groups

The descriptive measures for each of the cognate subjects completed by each of the two groups, TVET N4 and SC/NSC, are listed in Table 3 overleaf.

The SC/NSC and TVET N4 scores are the category ratings as displayed on the SC/NSC or TVET N4 certificates. For example, 80% or more is rated as 7 for the SC/NSC group (see Table 3). The university subjects are reflected by the mark obtained as a percentage. It is clear from Table 3 that the SC/NSC learners performed better than the TVET learners in Mathematics (5.38 vs 3.05), Physical Science (5.10 vs 2.95) and English (5.2 vs 4.43) in the SC/NSC examinations. It is noteworthy that although the learners did not have the required competency, they did have the relevant subjects.

School subject comparison

Figure 1 indicates the mean and standard deviation per school subject.

The SC/NSC university learners or those learners entering HE directly obtained higher marks in all subjects than the TVET N4 learners upon completion of their SC/NSC. There is only a marginal overlap in the spread, with the lower-end scores of the university learners' SC/NSC being in line with the upper-end scores of the TVET N4 learners' SC/NSC marks. This is understandable, as the entrance criteria to enrol at university are higher than those for a TVET college, and the reason the learners were not accepted directly into the HEI was their lower marks. The test of significance for the differences is shown in Table 4.

TABLE 3: Results

	Group											
	TVET N4						SC/NSC					
	Count	Mean	Standard Deviation	Median	1st Quartile	3rd Quartile	Count	Mean	Standard Deviation	Median	1st Quartile	3rd Quartile
English (B)	67	4.47	0.65	4.00	4.00	5.00	546	5.16	0.93	5.00	4.00	6.00
English (A)	67	4.33	0.59	4.00	4.00	5.00	546	5.32	0.79	5.00	5.00	6.00
Combined English	67	4.43	0.63	4.00	4.00	5.00	546	5.20	0.89	5.00	5.00	6.00
Physical Science	67	2.95	1.25	3.00	2.00	3.00	546	5.10	0.89	5.00	4.00	6.00
Mathematics	67	3.05	1.37	3.00	2.00	4.00	546	5.38	0.89	5.00	5.00	6.00
TVET N4 Engineering Science	67	5.45	0.74	5.00	5.00	6.00	546					
TVET N4 Industrial Electronics	67	6.00	0.98	6.00	5.00	7.00	546					
TVET N4 Mathematics	67	6.10	0.96	6.00	5.00	7.00	546					
TVET N4 Electrotechnics	67	6.60	1.09	7.00	6.00	8.00	546					
Projects I	67	61.30	15.38	65.00	58.00	70.00	546	55.92	19.56	60.00	50.00	69.00
Electrical Engineering I	67	54.39	15.15	57.00	45.00	66.00	546	56.96	15.49	58.00	46.00	68.00
Electronics I	67	51.57	13.34	52.00	45.00	61.00	546	48.81	14.03	51.00	39.00	58.00
Mechanics I	67	38.28	10.22	38.00	33.00	46.00	546	41.15	11.58	39.00	34.00	47.00
Communication Skills I	67	60.79	9.96	61.00	58.00	65.00	546	61.54	10.52	62.00	55.00	68.00
Computer Skills I	67	73.06	15.45	75.00	61.00	87.00	546	72.84	15.06	75.00	64.00	84.00
Mathematics I	67	61.80	16.22	63.50	52.00	73.00	546	60.95	16.42	61.00	50.00	72.00

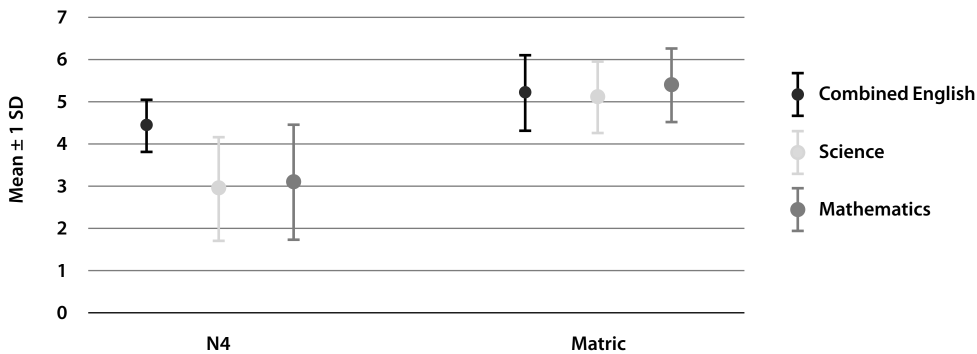

FIGURE 1: Entrance subjects for TVET N4 and SC/NSC (Matric)

TABLE 4: Significance test

	English (B)	English (A)	Combined English	Physical Science	Mathematics
Mann-Whitney U	5 803.500	467.000	9 632.000	2 621.000	2 798.000
Wilcoxon W	7 028.500	638.000	11 910.000	4 274.000	4 751.000
Z	–4.937	–4.691	–6.658	–10.849	–11.278
Asymp Sig (2-tailed)	<0.001	<0.001	<0.001	<0.001	<0.001

The *p*-values are all significant ($p < 0.001$). This implies that there is a significant difference in the central values. It is noted in Table 4 and in Figure 2 that the SC/NSC university learners had significantly higher scores than the TVET N4 learners.

University subject comparison

Although there is variation in the marks between the subjects, as seen in Figure 2, the marks obtained per subject seem similar between the groups. Most of the subject means (medians) are similar, as is the spread. In order to test the claim that there is no significant difference in the central values by subject between the groups, a Mann-Whitney test was performed. The results are shown in Table 5.

The results show that there are no significant differences for the subjects between the groups for all subjects except Projects 1 (as all the *p*-values are greater than 0.05). This implies that the TVET N4 learners are performing just as well as the SC/NSC university learners in the same subjects.

From Figure 2 and Table 5 it is noted that the TVET N4 learners had marginally higher scores in three of the seven subjects, with the SC/NSC university learners having higher scores in three others. The TVET N4 learners have a significantly higher score for Projects 1 ($p = 0.013$). This may be due to their completing practical components in their courses at the TVET colleges and possible exposure to industry.

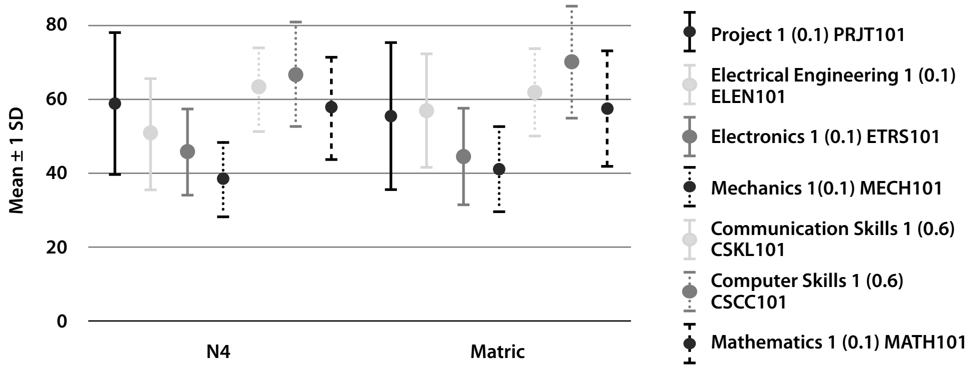

FIGURE 2: University subject comparison

TABLE 5: Significance test of university subjects

	Projects I	**Electrical Engineering I**	**Electronics I**	**Mechanics I**	**Communication Skills I**	**Computer Skills I**	**Mathematics I**
Mann-Whitney U	14 723.000	16 073.500	15 954.500	3 304.500	17 122.500	17 326.500	16 436.500
Wilcoxon W	160 793.000	18 284.500	164 739.500	3 629.500	19 400.500	155 927.500	156 621.500
Z	–2.496	–1.189	–1.687	–0.938	–0.353	–0.223	–0.775
Asymp Sig (2-tailed)	**0.013**	0.235	0.092	0.348	0.724	0.824	0.438

Cross-tabulations

A chi-square test of independence was performed to determine whether there was a statistically significant relationship between the group and passing. The null hypothesis states that there was no association between the two. The alternative hypothesis indicates that there was an association. Table 6 summarises the results of the chi-square tests.

Overall, the ratio of TVET N4 learners to SC/NSC university learners is approximately 1 : 9 (10.9% : 89.1%) (p <0.001). In the category of learners who progressed (Yes), 12.0% were TVET N4 learners. In the category of TVET N4 learners (only), 77.6% passed. This category of TVET N4 learners who passed formed 8.5% of the total sample. (This is an expected smaller overall number in terms of the learners' group ratio.) It is also noteworthy that a slightly larger proportion of TVET N4 learners progressed than SC/NSC university learners (77.6% compared to 70.0%).

TABLE 6: Chi-squared test

			Group		Total
			TVET N4	**SC/NSC**	
Progressed	**No**	**Count**	15	164	179
		% within Progressed	8.4%	91.6%	100.0%
		% within Group	22.4%	30.0%	29.2%
		% of Total	2.4%	26.8%	29.2%
	Yes	**Count**	52	382	434
		% within Progressed	12.0%	88.0%	100.0%
		% within Group	77.6%	70.0%	70.8%
		% of Total	8.5 %	62.3%	70.8%
Total		**Count**	67	546	613
		% within Progressed	10.9%	89.1%	100.0%
		% within Group	100.0%	100.0%	100.0%
		% of Total	10.9%	89.1%	100.0%

Correlations

Bi-variate correlation was also performed on the data. The results are shown in Tables 7 and 8. Positive values indicate a directly proportional relationship between the variables; a negative value indicates an inverse relationship. All significant relationships are indicated by a * or **.

The null hypothesis states that there is no correlation between the variables. The alternative hypothesis states that there is a correlation between the variables. The various correlations are highlighted below.

SC/NSC subjects vs Semester 1 subjects

There is a significant correlation between school-level English and Communication ($r = 0.346$, $p = 0.004$).

TVET subjects

Each N4 subject has a good correlation with the other N4 subjects. This shows that subject content, subject level and teaching are congruent and that there is synergy between them.

TVET vs Semester 1 subjects

The correlations of the TVET subjects with the Semester 1 subjects are not significant. One correlation of interest is that N4 Electrotechnics does have a correlation with Electrical Engineering I. This is probably due to the content of the subjects being aligned.

TABLE 7: TVET N4 bi-variate correlation

		Combined English	N4 Engineering Science	N4 Engineering Mathematics	N4 Electrotechnics	N4 Industrial Electronics	Projects I	Electrical Engineering I	Electronics I	Mechanics I	Communication Skills I	Computer Skills I	Mathematics I
Combined English	**Pearson Correlation**	1											
	N	67											
N4 Engineering Science	**Pearson Correlation**	.033	1										
	N	57	57										
N4 Engineering Mathematics	**Pearson Correlation**	.173	.274**	1									
	N	67	67	67									
N4 Electrotechnics	**Pearson Correlation**	.005	.102	–.048	1								
	N	67	67	67	67								
N4 Industrial Electronics	**Pearson Correlation**	.001	.228**	.208**	.360*	1							
	N	67	67	67	67	67							
Projects I	**Pearson Correlation**	–.052	.099	–.039	.084	–.103	1						
	N	67	67	67	67	67	67						
Electrical Engineering I	**Pearson Correlation**	–.021	.017	.048	.158	–.276	.563**	1					
	N	67	67	67	67	67	67	67					
Electronics I	**Pearson Correlation**	–.018	.034	–.009	.135	–.082	.526**	.770**	1				
	N	67	67	67	67	67	67	67	67				
Mechanics I	**Pearson Correlation**	.050	.187	.006	.174	.021	.610**	.783**	.783**	1			
	N	25	25	25	25	25	25	25	25	25			
Communication Skills I	**Pearson Correlation**	.346**	.049	.186	.11	–.083	.189	.402**	.484**	.283**	1		
	N	67	67	67	67	67	67	67	67	25	66		
Computer Skills	**Pearson Correlation**	.036	.152	–.006	.137	–.18	.387**	.513**	.685**	.282**	.556**	1	
	N	67	67	67	67	67	67	67	67	25	67	67	
Mathematics I	**Pearson Correlation**	.110	.195	.089	.124	–.54	.312*	.675**	.643**	.281**	.423**	.584**	1
	N	67	67	67	67	67	67	67	67	25	67	67	67

a Group = TVET N4
** – *Correlation is significant at the 0.01 level (2-tailed).*
* – *Correlation is significant at the 0.05 level (2-tailed).*

Semester 1 subjects

Communication Skills I and Computer Skills I show a good correlation with all the Semester 1 subjects. These subjects are used with the 'main subjects'. It is essential that learners can communicate both verbally and in writing in the fields of technology. A positive correlation between the 'main subjects' indicates that subject content and teaching methodology are congruent.

TABLE 8: SC/NSC bi-variate correlation

		Combined English	Physical Science	Mathematics	Projects I	Electrical Engineering I	Electronics I	Mechanics I	Communication Skills I	Computer Skills I	Mathematics I
Combined English	**Pearson Correlation**	1									
	N	546									
Physical Science	**Pearson Correlation**	.246**	1								
	N	546	546								
Mathematics	**Pearson Correlation**	.056	.399**	1							
	N	546	546	546							
Projects I	**Pearson Correlation**	–.049	–.002	.019	1						
	N	540	540	540	540						
Electrical Engineering I	**Pearson Correlation**	.043	.272**	.256**	.407**	1					
	N	535	535	535	530	535					
Electronics I	**Pearson Correlation**	.005	.206**	.190**	.399**	.601**	1				
	N	545	545	545	539	535	545				
Mechanics I	**Pearson Correlation**	–.019	.311**	.380**	.280**	.641**	.537**	1			
	N	298	298	298	294	292	297	298			
Communication Skills I	**Pearson Correlation**	.345**	.081	.008	.255**	.394**	.404**	.251**	1		
	N	525	525	525	522	523	525	285	525		
Computer Skills I	**Pearson Correlation**	.173**	.057	.081	.264**	.344**	.396**	.215**	.523**	1	
	N	526	526	526	523	523	526	284	523	526	
Mathematics I	**Pearson Correlation**	–.057	.273**	.387**	.313**	.636**	.635**	.659**	.307**	.368**	1
	N	529	529	529	524	527	529	289	522	523	529

a Group = TVET N4
**** – *Correlation is significant at the 0.01 level (2-tailed).*
*** – *Correlation is significant at the 0.05 level (2-tailed).*

For this group of learners, there are significant directly proportional correlations between English and Science and between Science and Mathematics at the SC/NSC exit level. In addition, there is a positive correlation between English and Communication. There are also correlations between Science and Mathematics and various university subjects. There are also significant positive correlations between the university subjects.

SC/NSC subjects

There is a positive correlation of 0.246 between English and Physical Science, presumably because proficiency in English enables a better understanding of concepts and also enables one to communicate the correct terminology of Physical Science. There is also a good correlation of 0.399 between Mathematics and Physical Science, presumably due to the Mathematics content and analytical concepts in both subjects.

SC/NSC vs Semester 1 subjects

English has a positive correlation of 0.345 to Communication Skills I and to Computer Skills I of 0.173. Both of these subjects are 'soft skills' and are predominantly about communicating in English. Mathematics has a strong correlation to all the 'main' Semester 1 subjects: Electrical Engineering I (0.256), Electronics I (0.190), Mechanics I (0.380) and Mathematics I (0.387). All of these subjects include theory based on analysis and calculations; therefore, the stronger a learner is at the basic language of Mathematics, the more manageable the subject will be. Physical Science also has a strong correlation with these four subjects, for similar reasons. The strong correlation that Mathematics and Physical Science have with the four main subjects of Semester 1 is a good indication that these subjects are important selection criteria for learners entering the Department of Electrical Power Engineering (DEPE).

Semester 1 subjects

Communications Skills I and Computer Skills I show good correlations with all the Semester 1 subjects. These subjects are used with the 'main subjects'. It is essential that learners can communicate both verbally and in writing in the technology fields. Positive correlations between the 'main subjects' indicate that subject content and teaching methodology are congruent.

Binary logistic regression model

A binomial logistic regression predicts the probability that an observation falls into one of two categories of a dichotomous dependent variable based on one or more independent variables that can be either continuous or categorical. The progression of the learner (Pass or Fail) is used as the dependent variable. The outputs are explained in Table 9.

TABLE 9: Binary logistic regression model output summary

Step	–2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	127.596[a]	0.602	0.815
a. Estimation terminated at iteration No. 8 because parameter estimates changed by less than .001.			

Table 9 contains the Cox & Snell R Square and the Nagelkerke R Square values. These are both methods of calculating the explained variation. These values are sometimes referred to as *pseudo R2* values (and will have lower values than in multiple regression). They are, however, interpreted in the same manner, but with more caution. The explained variation in the dependent variable based on the model therefore ranges from 60.2% to 81.5%, depending on whether the Cox & Snell *R2* or the Nagelkerke *R2* methods are referenced respectively.

There is a high percentage of cases that can be correctly classified (91.1%), as seen in Table 10.

TABLE 10: Classification table

Observed			Predicted		
			Progressed		Percentage Correct
			No	Yes	
Step 1	**Progressed**	**No**	104	16	86.7
		Yes	11	173	94.0
	Overall Percentage				**91.1**
a. The cut value is 0.500					

The Wald test is used to determine the statistical significance of each of the independent variables. The statistical significance of the test is found in the 'Sig.' column, as seen in Table 11. From these results it is noted that Projects I (0.1) PRJT101, Electrical Engineering I (0.1) ELEN101, Electronics I (0.1) ETRS101, Mechanics I (0.1) MECH101 and Mathematics I (0.1) MATH101 added significantly to the model or prediction, but the others did not.

The probability of an event occurring based on a one-unit change in an independent variable when all the other independent variables are kept constant can be predicted using the odds ratio (Exp(B)). For example, Table 11 shows that the odds of passing Semester 1 are 4.951 times greater for TVET N4 learners than the SC/NSC university group, even though the *p*-value is not significant.

Most coefficients (B) are positive, which suggests that the probability of passing is greater with higher marks. This may be obvious, but it indicates that the highlighted *p*-value subjects show greater chances of passing compared to the non-highlighted ones. Even though it is not significant, Communication Skills shows a marginal decrease in the pass rate (–0.053). The odds ratio for all the other subjects is approximately 1.

TABLE 11: Variable in the equation

		B	SE	Wald	Df	Sig.	Exp(B)	95% CI for EXP(B)	
								Lower	Upper
Step 1a	Group (1)	1.600	0.992	2.600	1	0.107	**4.951**	0.708	34.606
	Projects I	0.095	0.020	22.259	1	**0.000**	1.100	1.057	1.145
	Electrical Engineering I	0.133	0.028	22.975	1	**0.000**	1.142	1.082	1.206
	Electronics I	0.120	0.028	18.095	1	**0.000**	1.128	1.067	1.192
	Mechanics I	0.100	0.035	8.367	1	**0.004**	1.105	1.033	1.183
	Communication Skills I	–0.053	0.029	3.444	1	0.063	0.948	0.896	1.003
	Computer Skills I	0.029	0.019	2.236	1	0.135	1.029	0.991	1.068
	Mathematics I	0.136	0.028	24.392	1	**0.000**	1.146	1.085	1.209
	Constant	–27.604	4.166	43.896	1	0.000	0.000		

a. Variable(s) entered on step 1.

Cohort analysis

Tables 12 to 16 show a cohort analysis over the period 2013 to 2017, as per the DHET reporting standard, namely, first time registering learners for the HE institution and completing in minimum time (three years), minimum time + 1 (four years), and minimum time + 2 (five years).

TABLE 12: Cohort study of three-year programmes, learners entering for first time, 2013

SC/ NSC/ TVET	No. first-time entering 2013	No. graduated in			No. returning in 2018	Throughput rate			No. dropped out	Dropout rate	Still in progress
		2015	2016	2017		Min. time*	Min. time + 1*	Min. time + 2*			
SC/ NSC	171	8	44	22	10	**5%**	**26%**	**13%**	87	51%	6%
TVET	37	1	9	8	7	**3%**	**24%**	**22%**	12	32%	19%
Total	**208**	**9**	**53**	**30**	**17**	**4%**	**25%**	**14%**	**99**	**48%**	**8%**

** Min. time = completing the programme in three years; Min. time + 1 = four years and Min. time + 2 = five years.*

For the first cohort of learners, who registered for the first time in 2013, the throughput rates are comparable. These results show that the TVET learners graduate in relatively comparable numbers to the SC/NSC learners.

TABLE 13: Cohort study of three-year programmes, learners entering for first time, 2014

SC/ NSC/ TVET	No. first-time entering 2014	No. graduated in			No. returning in 2019	Throughput rate			No. dropped out	Dropout rate	Still in progress
		2016	2017	2018		Min. time	Min. time + 1	Min. time + 2			
SC/NSC	188	8	26	19	11	**4%**	**14%**	**10%**	124	66%	6%
TVET	21	0	1	5	1	**0%**	**5%**	**24%**	14	67%	5%
Total	**209**	**8**	**27**	**24**	**12**	**4%**	**13%**	**11%**	**138**	**66%**	**6%**

For this cohort there are appreciable differences in the throughput rates for minimum time and minimum time + 1, but a huge improvement in the throughput rate for minimum time + 2.

TABLE 14: Cohort study of three-year programmes, learners entering for first time, 2015

SC/ NSC/ TVET	No. first-time entering 2015	No. graduated in			No. returning in 2020	Throughput rate			No. dropped out	Dropout rate	Still in progress
		2017	2018	2019		Min. time	Min. time + 1	Min. time + 2			
SC/NSC	123	11	23	18	9	**9%**	**19%**	**15%**	62	50%	7%
TVET	34	1	1	10	4	**3%**	**3%**	**29%**	18	53%	12%
Total	**157**	**12**	**24**	**28**	**13**	**8%**	**15%**	**18%**	**80**	**51%**	**8%**

The TVET learners in this cohort fall behind the SC/NSC learners in minimum time and minimum time + 1 but catch up tremendously in minimum time + 2.

TABLE 15: Cohort study of three-year programmes, learners entering for first time, 2016

SC/ NSC/ TVET	No. first-time entering 2016	No. graduated in			No. returning in 2021	Throughput rate			No. dropped out	Dropout rate	Still in progress
		2018	2019	2020		Min. time	Min. time + 1	Min. time + 2			
SC/NSC	89	4	14	12	11	**4%**	**16%**	**13%**	48	54%	12%
TVET	21	2	8	2	0	**10%**	**38%**	**10%**	9	43%	0%
Total	**110**	**6**	**22**	**14**	**11**	**5%**	**20%**	**13%**	**57**	**52%**	**10%**

In this cohort, the TVET learners outperform the SC/NSC learners in both minimum time and minimum time + 1 and have a similar result for minimum time + 2.

Table 16: Cohort study of three-year programmes, learners entering for first time, 2016

SC/NSC / TVET	No. First-time Entering 2017	No. Graduated in		No. Returning in 2021	Throughput Rate		No. Dropped out	Dropout Rate	Still in Progress
		2019	2020		Min Time	Min Time + 1			
SC/NSC	76	2	10	20	**3%**	**13%**	44	58%	26%
TVET	25	0	4	6	**0%**	**16%**	15	60%	24%
Total	**101**	**2**	**14**	**26**	**2%**	**14%**	**59**	**58%**	**26%**

For the 2017 cohort, the throughput rates for minimum time and minimum time + 1 are comparable.

Discussion

The most common admission routes for learners to be admitted to the UoT are, first, via SC/NSC, the 'traditional' route on exiting school; second, there is transfer from a traditional university, usually to avoid academic exclusion from such an institution; and third, articulation from a TVET college. The second route did not form part of this investigation as learners transferring from degrees at a traditional university usually enter from the second or third semester onwards, depending on credits they obtained. The SC/NSC is the usual route and was used as a control group in this study. The focus of this study is the cohort of learners articulating from the TVET/FET (Further Education and Training) college into the Engineering Department at the UoT. There is a supply shortage of learners with the STEM subjects at the required levels for all academic institutions. The statistical analysis has shown that learners who entered DEPE from a TVET college upon completion of the TVET N4 Electrical Certificate with N4 Engineering Mathematics, N4 Engineering Science, N4 Electrotechnics and N4 Industrial Electronics performed as well as, if not better than, SC/NSC learners in first-semester subjects for the National Diploma: Electrical Engineering. The analysis of the throughput of the SC/NSC learners, over five separate cohorts as per the DHET reporting standard – namely, a tracked cohort of learners registering for the first time at an HE institution and completing in minimum time (three years), minimum time + 1 (four years), and minimum time + 2 (five years) – demonstrates that there is no definitive difference between the throughput rates of articulating TVET learners and SC/NSC learners. Articulation therefore may provide other HE departments with a viable means of meeting their enrolment targets.

Concluding remarks

Many learners leave the school system without the necessary entrance requirements to be admitted directly into an HEI. Through articulation, they have a second chance to attend an HEI. Articulation, as defined in the Articulation Policy for Post-School Education and

Training System of South Africa, stipulates, among other things, that if a learner completes a course at one institution and has gained the relevant knowledge and skills at the necessary levels, this must be recognised by other institutions if the knowledge gained is sufficient to allow epistemological access to programme(s) that the learner wants to enter (DHET, 2017). Learners must be supported in their individual learning and work pathways. Through articulation and being directed to TVET colleges to acquire the relevant subjects, learners can gain access to their chosen programme. At least in the context of admission to the Engineering Department at a UoT via 'articulation as a stairwell', this study has served to debunk the notion that TVET qualifications and their learners are inferior and unworthy of pursuing studies at a UoT.

REFERENCES

Blom, R. 2013. *Articulation in the South African education and training system*. Johannesburg: University of the Witwatersrand.

Bogdan, R & Biklin, S. 1998. *Qualitative research for education: An introduction to theory and methods.* Boston, MA: Allyn and Bacon.

Boston College – Lynch School of Education. 2019. *The trends in international Maths and Science study (TIMSS)* [Online]. Boston College. Available at: https://timssandpirls.bc.edu/timss2019/index.html [Accessed 18 July 2022].

Bundy, C. 2006. Global patterns, local options? Changes in higher education internationally and some implications for South Africa. *Ten years of higher education under democracy*. Pretoria: Council on Higher Education, 1–20.

Case, J. 2006. Issues facing engineering education in South Africa. *Proceedings of the 2006 3rd African Regional Conference on Engineering Education.* Pretoria, 26–27.

CHE (Council on Higher Education). 2015. *Content analysis of the baseline institutional submissions for Phase 1 of the quality enhancement project.* Pretoria: CHE.

Cook, T & Campbell, D. 1979. *Quasi-experimentation: Design and analysis issues for field settings.* Boston, MA: Houghton Mifflin.

Cooper, D & Subotzky, G. 2001. *The skewed revolution: Trends in South African Higher Education, 1988–1998*. Bellville: University of the Western Cape, Education Policy Unit.

Cosser, M. 2010. The skills cline: Higher Education and the supply–demand complex in South Africa. *Higher Education Journal*, 59(1):43–53.

Creswell, J. 2003. *Research design: Qualitative, quantitative, and mixed methods approaches.* Thousand Oaks, CA: Sage.

DBE (Department of Basic Education). 2012. *National Senior Certificate Examination Technical Report.* Pretoria: DBE.

DHET (Department of Higher Education and Training). 2009. *National Qualifications Framework (Act 67 of 2008)*. Pretoria: Government Printer.

DHET (Department of Higher Education and Training). 2013. *General and Further Education and Training Qualifications Sub-Framework (GFETQSF) and Higher Education Qualifications Sub-Framework (HEQSF)*. Pretoria: Government Printer.

DHET (Department of Higher Education and Training). 2017. *The Articulation Policy for the Post-school Education and Training System of South Africa (PSET).* Pretoria: Government Printer.

DOE (Department of Education). 2001. *National Plan for Higher Education*. Pretoria: Government Printer.

DOL (Department of Labour). 2010. *Skills shortages in South Africa: Case studies of key professions*. Pretoria: Government Printer.

Engineering Council of South Africa (ECSA) Annual Report. 2017/2018. Johannesburg ECSA.

Graham, B, Lortan, D, Maistry, S & Walker, M. 2017. Using espistemic justice as a framework for underpinning articulation between technical and vocational education and training colleges and higher education engineering programmes. In B Collier-Reed (ed.) *Proceedings of the 4th Biennial Conference of the South African Society for Engineering Education.* Cape Town, South Africa, 94.

IEEE (Institute of Electrical and Electronics Engineers). 2013. *Spectrum forecasters STEM survey report.* Third quarter. by Advanced Technology for Humanity. Available at: https://www.resurchify.com/impact/details/17318#:~:text=IEEE%20Spectrum%20Impact%20Score%202021,2022%20as%20per%20its%20definition. [Accessed 20 November 2020].

Lawless, A. 2005. *Numbers & needs: Addressing imbalances in the civil engineering profession*. South African Institution of Civil Engineering (SAICE).

Lotz-Sisitka, H. 2015. *Close-out report for SAQA*. Grahamstown: Rhodes University Research Partnership for Learning Pathways.

Mackenzie, N & Knipe, S. 2006. Research dilemmas: Paradigms, methods and methodology. *Issues in Educational Research*, 16(2):193–205.

Malale, M & Gomba, G. 2016. Stakeholders' perceptions about technical and vocational education and training colleges in South Africa: A literature review. Proceedings of the 2016 South African International Conference on Education: Towards excellence in educational practices.

Mawoyo, M. 2014. *Student access and success: Issues and interventions in South African universities*. Inyathelo: The South African Institute for Advancement.

McGhie, V. 2014. The will to learn: An essential element for successful student learning? *Progression*, 36(1):108–128.

Mertens, D. 2005. *Research methods in education and psychology: Integrating diversity with quantitative and qualitative approaches.* Thousand Oaks, CA: Sage.

Ng'ethe, N, Subotzky, G & Afeti, G. 2008. Differentiation and articulation in tertiary education systems: A study of twelve African countries. *World Bank Working Papers*.

O'Leary, Z. 2004. *The essential guide to doing research.* London: Sage.

Oosthuizen, M, Garrod, N & Macfarlane, B. 2009. *South Africa: (Re)forming a sector. Challenging boundaries managing the integration of post-secondary education.* London: Routledge.

Reddy, V. 2006. *Mathematics and Science achievement at South African schools in TIMSS 2003.* Cape Town: HSRC Press.

Ross, S & Gray, J. 2005. Transitions and re-engagement through second chance education. *The Australian Educational Researcher*, 32(3):103–140.

RSA (Republic of South Africa). 1996. *Constitution of the Republic of South Africa, Chapter 2: Bill of Rights (Education)* [Online]. Pretoria. Available at: https://www.gov.za/documents/constitution/chapter-2-bill-rights#29 [Accessed 25 November 2020].

SAQA (South African Qualifications Authority). 2017. Articulation between technical and vocational education and training (TVET) colleges and higher education institutions (HEIs). *National Articulation Baseline Study Report*, October.

SAQA (South African Qualifications Authority). 2019. *Strengthening Learning-and-Work Pathways in Community Development, Early Childhood Development and Engineering: Report on the 3rd NQF Conference*. Johannesburg: SAQA.

Scott, I. 2014. *Overcoming global predictors of failure in higher education: An essential condition for widening successful participation in the developing world.* University of Salford, England.